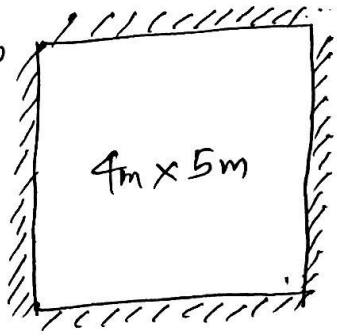
Q: Design a simply supported slab for a room of internal dimensions 4m × 5m. Slab is subjected to 3 kN/m² live load and 1 kN/m² finish load. Use M20 concrete & Fe415 steel. Assume slab corners are held down. (or prevented from lifting up)

Ans:



This is a torsionally restrained slab

1. Determine type of slab.

$$\frac{L}{B} = \frac{5}{4} = 1.25 < 2$$

$\Rightarrow$ Two-way slab

2. Determining depth of slab.

Shorter effective span l_x = clear span (4.00 m) + support width (Assume as 0.23 m)

$$= 4.00 + 0.23$$

$$= 4.23\text{ m} = 4230\text{ mm}$$

$$\frac{l_x}{d} \leq 20 \times \text{Modification factor}$$

(= 1.5 for two-way slabs)

$$\frac{4230}{d} \leq 20 \times 1.5$$

$$\Rightarrow d \geq 141\text{ mm}$$

Take $d = 145$ mm

Take effective cover = 25 mm

$\therefore$ Overall depth of slab $D = 145 + 25 = 170$ mm

2. finding effective span

l_x = min of { c/c dist b/w supports = 4.23 m ; clear span + d = 4.00 + 0.175 = 4.175 m ✓ }

= 4.145 m ✓

l_y = min of { 5.00 + 0.23 = 5.23 m ; 5.00 + 0.145 = 5.145 m ✓ }

= 5.145 m ✓

4. Find moment to be resisted by slab:

W_{DL} = 25 kN/m³ × 1m × 0.17m = 4.25 kN/m

W_{LL} = 3 kN/m² × 1m = 3 kN/m

W_{FL} = 1 kN/m² × 1m = 1 kN/m

Total load w = 8.25 kN/m

factored load $W_u = 1.5\,w = 1.5 \times 8.25$

$= 12.375$ kN/m

Moment to be resisted by slab is given by:

$M_x = \alpha_x W_u l_x^2$, $M_y = \alpha_y W_u l_x^2$

$\alpha_x = 0.075$

$\alpha_y = 0.056$

$l_y/l_x = \frac{5.145}{4.145} = 1.24$

for

$l_y/l_x = 1.2 \rightarrow \alpha_x = 0.072$

$l_y/l_x = 1.3 \rightarrow \alpha_x = 0.079$

$M_x = 0.075 \times 12.375 \times 4.145^2$

$= 15.95$ kNm

$M_y = 0.056 \times 12.375 \times 4.145^2$

$= 11.91$ kNm

5. To find depth of neutral axis:

Along shorter span

$M_x = 0.36 f_{ck} b x_u (d - 0.42 x_u)$

$\Rightarrow 15.95 \times 10^6 = 0.36 \times 20 \times 1000 x_u (145 - 0.42 x_u)$

$\Rightarrow 3024 x_u^2 - 1044000 x_u + 15.95 \times 10^6 = 0$

$\Rightarrow x_u = \underline{16 \text{ mm}}$

Along longer span

$M_y = 0.36 f_{ck} b x_u (d - 0.42 x_u)$

$\Rightarrow 11.91 \times 10^6 = 0.36 \times 20 \times 1000 x_u (145 - 0.42 x_u)$

$\Rightarrow 3024 x_u^2 - 1044000 x_u + 11.91 \times 10^6 = 0$

$\Rightarrow x_u = \underline{11.80 \text{ mm}}$

$x_{umax} = 0.48 d$ (Fe415 steel)

$= 0.48 \times 145 = \underline{69.60 \text{ mm}}$

Since x_u along both spans $< x_{umax}$

$\Rightarrow$ Underreinforced section

$\therefore$ Safe

6. Determining area of steel for shorter span

$$x_u = \frac{0.87 f_y A_{st}}{0.36 f_{ck} b}$$

$$\Rightarrow 16 = \frac{0.87 \times 415 A_{st}}{0.36 \times 20 \times 1000}$$

$$\Rightarrow A_{st} = 319 \text{ mm}^2$$

Assume 12mm ϕ bars, spacing $s = 1000 A_b / A_{st}$

$$= 100 \times \frac{\pi/4 \times 12^2}{319}$$

$$= 355 \text{ mm}$$

spacing $s \leq 3d$ or 300mm, whichever is less

$\leq (3 \times 145)$ or 300mm "

$= 435$ mm

≤ 300 mm ✓

$\Rightarrow$ Provide mainbars along shorter span as 12mm ϕ @ 300 mm c/c

7. Determining area of steel for longer span

$$x_u = \frac{0.87 f_y A_{st}}{0.36 f_{ck} b}$$

$$\Rightarrow 11.8 = \frac{0.87 \times 415 A_{st}}{0.36 \times 20 \times 1000}$$

$$\Rightarrow A_{st} = 235 \text{ mm}^2$$

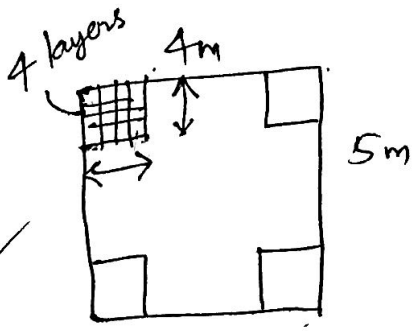
Assume 12mm ϕ bars. $\therefore$ spacing $s = 1000 \times \frac{\pi/4 \times 12^2}{235}$

$$= 481 \text{ mm}$$

But spacing of main bars ≤ 300mm

$\Rightarrow$ Provide mainbars along longer span as : 12mm ϕ @ 300mm c/c

8. Since it is torsionally restrained two-way slab, we must provide torsion reinforcements



Extend of torsion reinforcements $= \frac{l_x}{5}$

$= \frac{4.145}{5}$

$= 0.83m$ ✓

Area of torsion reinforcement in each layer $= \frac{3}{4} A_{st,x}$

$= \frac{3}{4} \times 319$

$= 240\ mm^2$

Assume 8mm ϕ bars,

spacing of torsion reinforcents in each layer

$=$ width of torsion layer $\times \frac{A_b}{A_s(\text{torsion})}$

$= 830 \times \frac{\pi/4 \times 8^2}{240}$

$= 173\ mm$

$\Rightarrow$ Provide 8mm ϕ torsion reinforcements @ 170mm c/c in each of 4 layers at all the slab corners

Q: Design a simply supported slab for a room of dimension 4m × 5m. Slab is subjected to 3 kN/m² liveload & 1 kN/m² finish load. Use M20 concrete & Fe415 steel. Assume slab corners are free to lift up.

Ans:

1. Determining type of slab:

$$\frac{L}{B} = \frac{5}{4} = 1.25 < 2 \Rightarrow \text{Two-way slab}$$

This is a torsionally unrestrained slab.

2. Determining slab depth

Shorter effective span l_x = clear span (4m) + support width (0.23m)

$= 4 + 0.23 = \underline{4.23\text{m}}$

$$\frac{l_x}{d} \leq 20 \times \text{Modification factor}\ (1.50)$$

$$\frac{4230}{d} \leq 20 \times 1.50$$

$\Rightarrow d \geq 141$ mm

Taking $d = 145$ mm

Effective cover = 25 mm

∴ Overall depth of slab = $145 + 25 = \underline{170\text{ mm}}$

3. finding effective span:

$$l_x = \min \begin{cases} 4.23\,m \\ 4 + 0.145 = 4.145\,m \end{cases} \Big\} = 4.145\,m$$

$$l_y = \min \begin{cases} 5 + 0.23 = 5.23\,m \\ 5 + 0.145 = 5.145\,m \end{cases} \Big\} 5.145\,m$$

4. Determing Moment of resistance of slab:

$W_{DL} = 25\,kN/m^3 \times 1m \times 0.17m = 4.25\,kN/m$

$W_{LL} = 3\,kN/m^2 \times 1m = 3\,kN/m$

$W_{FL} = 1\,kN/m^2 \times 1m = 1\,kN/m$

Total load $W = 8.25\,kN/m$

factored load $W_u = 1.5\,W = 1.5 \times 8.25$

$= 12.375\,kN/m$

$M_x = \alpha_x W_u l_x^2$ $\qquad$ $M_y = \alpha_y W_u l_x^2$

$\alpha_x = 0.087$

$\alpha_y = 0.057$

$\frac{l_y}{l_x} = \frac{5.145}{4.145} = 1.24$

$\therefore M_x = 0.087 \times 12.375 \times 4.145^2 = 18.50\,kNm$

$M_y = 0.057 \times 12.375 \times 4.145^2 = 12.12\,kNm$

5. Find depth of neutral axis :

for shorter span

$$M_x = 0.36 f_{ck} b x_u (d - 0.42 x_u)$$

$$18.50 \times 10^6 = 0.36 \times 20 \times 1000 \times x_u (145 - 0.42 x_u)$$

$$\Rightarrow 3024 x_u^2 - 1044000 x_u + 18.50 \times 10^6 = 0$$

$$\Rightarrow x_u = \underline{18.73 \text{ mm}}$$

for longer span

$$M_y = 0.36 f_{ck} b x_u (d - 0.42 x_u)$$

$$12.12 \times 10^6 = 0.36 \times 20 \times 1000 x_u (145 - 0.42 x_u)$$

$$\Rightarrow 3024 x_u^2 - 1044000 x_u + 12.12 \times 10^6 = 0$$

$$\Rightarrow x_u = \underline{12.03 \text{ mm}}$$

Now find x_{umax} :

$$x_{umax} = 0.48 d \quad \text{(for fe415)}$$

$$= 0.48 \times 145 = \underline{69.60 \text{ mm}}$$

Since x_u for both spans $< x_{umax}$

$\Rightarrow$ Underreinforced section.

6. finding steel area for shorter span

$$x_u = \frac{0.87 f_y A_{st}}{0.36 f_{ck} b}$$

$$18.73 = \frac{0.87 \times 415 A_{st}}{0.36 \times 20 \times 1000} \Rightarrow A_{st} = 374 \text{ mm}^2$$

Assume 12mm ϕ bars, Spacing $S = 1000 \frac{A_b}{A_{st}} = 1000 \times \frac{\pi/4 \times 12^2}{374}$

$$= \underline{302 \text{ mm}}$$

Spacing for main bars $\leq 3d$ or 300 mm, whichever is less

$\leq (3 \times 145) = 435$ mm or 300 mm, "

≤ 300 mm

Provide 12 mm ϕ @ 300 mm c/c along shorter span

7. Find steel area for longer span

$$x_u = \frac{0.87 f_y A_{st}}{0.36 f_{ck} b}$$

$$12.03 = \frac{0.87 \times 415 A_{st}}{0.36 \times 20 \times 1000} \Rightarrow A_{st} = 240 \text{ mm}^2$$

Assume 12 mm ϕ bars, spacing $s = 1000 \times \frac{\pi/4 \times 12^2}{240}$

$= 470$ mm

Spacing $\leq 3d$ or 300 mm, whichever is less

≤ 300 mm

Provide 12 mm ϕ Main bars @ 300 mm c/c along longer span